east; 2d, a few highs moved slowly over the Lakes and swung around to the southeast on the Atlantic coast; 3d, lows starting in the west filled up before reaching the Lakes.

1878.

Wet.—Cause: 1st, much rain came from Gulf cyclones; 2d, there seemed to be also a locus of low areas in Minnesota.

1882.

Dry.—Due to the persistency of high areas over the Lake region and just a little south.

1886.

Wet.—Due, 1st, to a tendency to a permanent low area much disturbed in the north; 2d, most rain from troughs reaching across country to Texas and Gulf; 3d, there was a permanent and well-marked high area over the south Atlantic, and this may have assisted in giving rain in connection with the northern low disturbed region.

1888.

Dry.—Due to a passage of high after high over the Lakes and to a delay or sluggishness of highs as they moved alone.

1890.

Wet.—Due, 1st, to a disturbed region over the Lakes; 2d, some troughs; 3d, marked storms passed over the Lakes; 4th, there seemed a remarkable tendency to rain from north winds blowing out of highs but without any storm conditions to south.

1891.

Dry.—It is an interesting fact that the monthly mean isobars and wind directions for 1891 are almost exactly the same as for 1878 and 1890, both of which were very wet. Cause: 1st, wide extended highs moved over the Lakes and then to the south Atlantic States. The high in this region can hardly be said to have been permanent as in the wet September of 1886, but it was rather continually added to by fresh and dry highs coming from the north, i. e., the permanency was not sufficient to cause a strong flow of rather damp air from the Ocean or Gulf northward; 2d, there was a rather persistent low in the extreme northwest, from which, however, very few disturbed areas passed out, but these drew up the dry, warm air from the south; 3d, winds were mostly south and dry from dry highs.

It is not thought that there is much that is new in what has gone before. It is rather a collection of views which have been picked up from time to time but now brought together. It is impossible to lay down any but the broadest generalizations. Each map will need a treatment by itself, especially when any one map happens to show a combination of all or nearly all the points here assembled from a study of 1,290 maps.

II.—THE CONNECTION BETWEEN SUN SPOTS AND THE WEATHER.

By Prof. FRANK H. BIGELOW (written in July, 1895).

At the request of the Chief of the Weather Bureau an attempt was made in June, 1894, to take photographs of the sun spots on clear days. The only telescope available for this work was a 4-inch Clark visual objective, and, after some experiments, it was concluded that the pictures thus obtained were not sufficiently superior to screen diagrams to justify the time and labor of making them. Accordingly the series for the past year consists of hand-drawn diagrams of the approximate relative positions and sizes of the spots, the diameter of the image of the sun being 85 millimeters.

In order to determine whether there is any law that controls the production of spots on the several meridians of the sun, it is necessary to resort to a long series of observations. For this purpose the Carrington "Observations of the Spots on the Sun, November, 1853, to March, 1861, made at Redhill;" the "Beobachtungen der Sonnenflecken zu Anclam und Potsdam, von G. Spörer, January, 1861, to December, 1879;" the "Photographic Results of the Greenwich Observatory, 1878 to 1891" (the last volume received), are available. The gap—1892 to June, 1894—has not been conveniently filled, though it can be done in due time. If spots have a tendency to form on certain solar meridians, then, in order to classify these as they appear, rotation after rotation, it is necessary to know the exact period of the rotation of the sun itself. In the October number, 1893, of Astronomy and Astrophysics, I published (page 9) my final result of the discussion of the periodic action in the European magnetic field, namely, 26.67928 days, and have in other places explained its connection with the sun's angular motion at the equator. This period has been tested, so that it can now be stated that the same periodic action was found in 1841 and other years up to 1895 and that this period, departing from the epoch June 12.22, 1887, does not fall short more than one-tenth of a day in fifty years. The spots have been grouped according to the accurate ephemeris instead of using the approximation 26.68.

Since the Carrington and Spörer series, and the Sporer and Greenwich series each overlap each other a little, it is possible to reduce the diagrams of Carrington and Spörer to the scale of the Greenwich series, so that a set of numbers, consistent, from 1854 to 1895, can be tabulated to show the amount of spotted areas that have occurred on the several days of the 26.68-day period in about forty years. A result that shows a definite tendency to group the spots on certain meridians becomes at once a test of the value of this period, and also points to many conclusions important in solar physics, terrestrial physics, and meteorology. For convenience the unit of area is the one hundred thousandth of the visible surface instead of one millionth. Each spot area is entered once for all, either as occurring on the central meridian or else at a date whose interval from this meridian can be computed from the available data. Hence, the tables show the total area of the sun-spot groups for forty years, arranged strictly in the 26.68-day period. The Northern and the Southern Hemispheres were kept separate throughout the compilation, and the final sums are wholly independent of each other.

The table and diagram (see Chart IX) give the sums for each of the four series specified and the sum of all, and also the curves displaying this last summation.

In plotting the curves for the Northern and the Southern Hemispheres it is seen that they are inverted curves of the same type. On comparing them with the magnetic curve derived from the European magnetic field (Amer. Met. Journ., January, 1895), it is clear that the sun-spot curve for the Southern Hemisphere gives back the *direct* type, and the sun-spot curve for the Northern Hemisphere the *inverse* type of the terrestrial magnetic curve. This computation has been arranged throughout on the ephemeris with epoch June 12.22, 1887. The curves of the accompanying diagrams give the magnetic field direct for the Southern Hemisphere, and inverted for the Northern Hemisphere. The number and sequence of the maxima and minima, in spite of some looseness in the curves, point unmistakably to a fundamental physical process.

It will be remembered (Amer. Journ. Sci., Dec., 1894,) that this same primary periodic curve was found in the temperatures of the American meteorological system, together with the phenomenon of inversion, for which no cause was assigned. The lines of force of the solar magnetic field as they pass through the earth have been fully explained (Amer. Journ. Sci., Aug., 1895). The discussion of the sun-spot formations, herewith presented, makes it evident that during certain intervals the atmosphere of the earth is under the controlling influence of the southern magnetic hemisphere of the sun; and again, the transition being usually abrupt, it is under the control of the northern hemisphere of the sun. Since the sequence or procession of the highs and lows crossing the United States corresponds always to either the direct or the inverse types, allowing for the inevitable looseness of structure in the circulation, it follows that the solar action has the power to invert the entire atmospheric movement, not only in the United States but also over the whole hemisphere of the earth (Amer. Met. Journ., Sept., 1893, curve 15). The inference seems very simple that if this polar magnetic field can maintain an order of highs and lows and can invert the order, then this magnetic field either directly or indirectly is chiefly concerned in the production of the cyclonic and anticyclonic systems. By as much as this is true, grave doubt is thrown upon the soundness of the convectional hypothesis of Ferrel, and the dynamic or driven-eddy theory of Hann to account for our primary meteorological phenomenon. The truth seems to be that the atmosphere of the earth is under the influence of four great systems of impressed forces:

1. The stress of the earth's gravitation.
2. The deflecting forces of the earth's rotation.
3. The equatorial radiant energy of the electromagnetic field.
4. The polar magnetic radiant energy from the polar regions of the sun.

The first and second are constant forces; the third has a steady diurnal and annual period from astronomical conditions; the fourth is very variable and loosely constructed, depending upon solar action, and yet is the system by which weather conditions are chiefly produced. Heretofore the meteorological problem has sought its solution by combinations of the three systems of forces mentioned, but it is clear that one of the most influential sets of impressed forces has been entirely neglected.

SPECIAL CONTRIBUTIONS.

I.—TORNADO, MARCH 26, AT ALBANY, N. Y.

Mr. Alfred F. Sims, Weather Bureau observer at Albany, N. Y., reports on the tornado of March 26, at that place, as follows:

Thunder first heard 2.58 p. m.; loudest, 3.06 p. m.; last heard, 3.06 p. m. Storm came from southwest, moved southeastward to the Hudson River south of station, thence north. Temperature before storm, 47°; temperature afterward, 43°; direction of wind before, south; afterward, south. At 2.50 p. m. the clouds to the north and west of this station assumed a slate color, and at 2.55 p. m. the lower portion of the cloud formation took on a peculiar yellow tint at the bottom (such a tint as would result from the presence of a large quantity of sand particles). At 2.58 p. m. some rain fell and distant thunder was heard; the rain came from the southwest. As the heavy cloud formation neared the station, at 3 p. m., a rumble not unlike distant thunder was heard, and at 3.06 p. m. a flash of lightning was seen and thunder heard east of the tornado cloud. The wind came from the south and the principal cloud formation kept moving from a west to a northwesterly direction.

As the cloud first neared the river its motion of translation appeared to be checked and the front of the cloud area presented a "rolled back" appearance and began to turn northward, the front of the heavy clouds curved in and out and took on the general outline of the west bank of the Hudson River beneath. On the opposite side of the river, and at about a distance of about 500 feet, comparatively bright weather conditions prevailed.

The storm moved northward for a short distance, thence northeast. As the cloud area or mass began to turn the wind began to feel peculiarly cool and the snow had a hard covering—no hail fell. The snow was partly covered with ice; it was hard, like a fish scale, on one side. The snow changed to rain at 3.02 p. m., and ended at 3.25 p. m. After the storm had passed away the observer visited the south end of the city, and at a point on Quay street at the river front found that the stack of the Townsend Furnace Company was broken, the broken part hanging along side of the standing part. Some roofing, slate, and débris were scattered in Mulberry street in a southwest direction. The observer next visited the Gould Carriage Works, and one of the office force, a member of the firm, stated that he first noticed that a peculiar darkness was coming on, and heavy clouds, low down, were appearing in the west. Shortly after 3 p. m. he heard a peculiar hissing noise, following which came a flash of lightning and a loud clap of thunder. The next thing he knew his office room was filled with dust, and he thought the whole building was coming down. The workmen were badly frightened and rushed down stairs. Immediately before the commotion in the building the air outside his office was filled with shingles, pieces of wood, old shoes, and glass, all of which were carried in a general northerly direction. The foreman led me to the roof of the works. I examined the roof of the building and found a section 50 by 10 feet ripped off. The building from which the tin was ripped off is 5 feet higher than the adjacent structures.

The tin was torn from the southwest corner of the building in a northerly direction and hurled against the south side of the stack of the Townsend Furnace Company on the opposite side of the street. The corner of the fence opposite the Gould Carriage Works was blown down. On the Story property the windows were broken. On the northeast corner of Dallius and Cherry streets I found that a piece was taken out of the southeast side of the northeast chimney on Mr. R. B. Rock's dwelling, also 20 feet of a fire wall on the south side of the house was razed level with the roof, the structure and some bricks and coping carried away from the northwest corner of the building. Mr. Rock informed me that he had a coop on the roof which was carried away, and struck the chimney first and then the northwest corner of the roof, after which it fell to the sidewalk below. During or prior to the storm Mr. Rock was at the Aniline Works, on the corner of Vine street and Broadway, and he noticed heavy clouds moving from the west with the surface wind due south. Muddy water was scooped out from puddles in the streets and hurled for some distance. A 10-foot board fence and gate, also the broad roof of a small house farther east on Bassett street, were torn off and carried across the street, falling to the south. The north wall of a shed adjoining was pushed outward for some distance.

Mr. Landy, who was in Mr. Lynch's yard at the time of the storm, was pinned down by a heavy 10 by 12 foot gate. The river was choppy, and some boys stated that water was lifted out of the river. The water in the river was some 6 feet below the string piece that evening. Between 5.45 and 6 o'clock p. m., at the time when the observer was going over the ground traversed by the storm, dark clouds were seen forming west of Bassett street; they moved over the observer from the west. Some clouds were also moving from the south at about right angles to the west cloud area with clear sky between the two formations. In the merging process they survived and the resultant cloud area moved northward along the west bank of the Hudson. No thunder came from the tornado cloud proper; it presented a V-shaped, light appearance to the observer as it came head on.

Amount of damage estimated at $2,000.

The chart of the path of destruction, compiled by Mr. Sims, is omitted from this abstract.

II.—TORNADO, MARCH 20, 1895, AUGUSTA, GA.

The following report is by Mr. D. Fisher, Weather Bureau observer at Augusta, Ga.:

At 9 a. m.. March 20, 1895, a tornado struck the southwest portion of the city, moving in a path from southwest to northeast, occupying five minutes in traveling over a territory 3½ miles in length, thus having a progressive velocity of 42 miles per hour. The lower appendage of the cloud was similar in shape to a funnel and was distinctly seen by several persons; it was visible in the air at a distance varying from 50 to 150 feet above the ground. The tail or funnel while in midair was seen swinging violently from side to side, and the noise it made when near the earth resembled that emanating from a moving freight train at a distance. The atmospheric conditions preceding, attending, and for a short while following the storm were as follows: The clouds at 8 a. m. were of the stratus type, of a deep slate color, scudding along very low from south to north at a rapid rate, and presented a billowy or choppy appearance; humidity, 81 per cent; the southerly winds had a velocity of 10 miles per hour; the temperature was 65°; the air was quite warm and sultry, and while on the tower roof the observer experienced a peculiar sensation which almost approached exhaustion. The wind blew from the northeast until 5.40 a. m., east until 7.20 a. m., south until 9 a. m., then suddenly veered to west and northwest, increasing in force and attaining a maximum velocity of 22 miles from south at 8.55 a. m. The barometer was falling rapidly all morning, reading 29.46 at 9.20 a. m., quickly rising to 29.56 at 10.30 a. m., then falling again until 4 p. m., when the instrument indicated 29.43, after which a steady and rapid rise occurred. A light shower of rain had